Lessons without limit: how free-choice learning is transforming science and technology education

Lições sem limite: como o aprendizado por livre escolha vem transformando a educação em ciência e tecnologia

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Societies are becoming nations of lifelong learners supported by a vast infrastructure of learning organizations. The centers of this learning revolution are not schools, but a network of organizations and media (museums, libraries, television, books, and increasingly the Internet) supporting the public's ever-growing demand for free-choice learning – learning guided by a person's needs and interests. Science learning is an important part of this revolution. Traditional boundaries and roles distinguishing groups of science educators and institutions are disappearing. To not understand and embrace these changes will impede our ability to enhance science learning worldwide.

KEYWORDS: free-choice learning, museums, science education, lifelong learning, learning revolution.

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As sociedades estão se tornando nações de aprendizes vitalícios respaldados por vasta infra-estrutura organizacional. Os centros desta revolução no aprendizado não são as escolas, e sim uma rede de organizações e mídias (museus, bibliotecas, televisão, livros e cada vez mais a Internet) que sustentam a busca crescente do aprendizado por livre escolha conduzido pelas necessidades e interesses de cada pessoa. O aprendizado da ciência é parte importante desta revolução. Estão desaparecendo as fronteiras e papéis tradicionais que distinguiam os grupos de educadores e instituições de ciência. Não compreender e não abraçar estas mudanças inviabilizam nossa capacidade de promover o ensino da ciência em âmbito mundial.

PALAVRAS-CHAVE: aprendizado por livre escolha; museus; educação em ciência; aprendizado vitalício; revolução na aprendizagem.

There is a quiet revolution going on in education worldwide. Societies are rapidly becoming nations of lifelong learners supported by a vast infrastructure of learning organizations. However, the centers of this learning revolution are not the traditional educational establishment of schools and universities, but rather a vast network of organizations and media (museums, libraries, television, film, books, and increasingly the Internet) which support the public's ever-growing demand for free-choice learning – learning guided by a person's needs and interests (Falk and Dierking, 1998; Falk and Dierking, 2001; Falk and Dierking, in production).

Science and technology learning is an important part of this educational shift. People engage in science and technology learning every day, across their life spans – at home, at work, and out in the world; much of this is free-choice learning. As we strive to develop science interest, knowledge, and understanding worldwide, we need to be aware of the vast number of ways, ages, and places in which a person learns science across their lifetime. For as societies become increasingly 'learning societies', the traditional boundaries and roles that have distinguished various groups of science educators is disappearing. In the twenty-first century, free-choice learning institutions such as museums, the Internet, and broadcast media are assuming an ever more prominent role in providing the public with science learning opportunities. All of these represent important – in fact I would suggest essential – ways that we learn and, most importantly, *contextualize* our science knowledge and understanding throughout our lifetimes. If as science educators in the twenty-first century we truly want to move beyond the rhetoric of supporting lifelong science learning, it is critical that we recognize, understand, and learn how to facilitate free-choice learning as a powerful vehicle for lifelong learning – not as a nicety, or a supplement to the science learning engaged in at school and the university, but as an equally essential component of lifelong science learning. To not understand and embrace these institutions as valuable players in the science education infrastructure of a community is to seriously impede our ability to enhance science learning worldwide.

There is a tremendous need for this shift in mind-set. Although there is a great deal of discussion about improving the quality of science and technology worldwide, the solutions suggested, either implicitly or explicitly, all seem to focus on schooling and teaching. In this changing world, I would argue that we also need to recognize free-choice learning entities (museums, science centers, broadcast and print media, libraries, and community-based organizations) as important contributors to science learning, playing an equally important role as schools and universities. It is important to also involve the science educators choosing to "teach and facilitate" in free-choice science learning settings also.

My colleagues and I at the Institute for Learning Innovation, a research institute based in Annapolis, Maryland, with a mission of understanding, facilitating, and advocating for free-choice learning, believe there is a unique opportunity to be leaders in this arena, as well as agents of change for future generations, introducing innovative models of science learning to individuals, groups, and society across people's lifetimes. How can the field of science education play a leadership role in twenty-first-century free-choice science learning? This paper will describe the nature of the free-choice learning revolution and describe the potential that a greater appreciation for free-choice learning can have on our efforts to improve science and technology interest, understanding, and knowledge worldwide, focused on the three following objectives:

1) Describe the free-choice learning revolution in more detail, suggesting the potential role it can play educationally in societies around the world;
2) Discuss the need for an infrastructure of education and research that supports the facilitation of this type of science and technology learning and share some initial leadership efforts; and,
3) Encourage you to play an advocacy role within the science and technology education community with fellow educators and researchers and, most importantly, with administrators and politicians, by more clearly identifying and describing the vast number of ways and places in which people of all ages learn science.

The free-choice learning revolution

As world societies transition from being industrial to knowledge-based, learning across the life span becomes ever more important. Children *and* adults are spending more and more of their time learning, not just in classrooms or on the job, but through free-choice learning at home, after work, and on weekends. All around the world, societies are witnessing a virtual explosion in opportunities for free-choice learning, learning which is guided by a person's needs and interests and which people engage in throughout their lives to find out more about what is useful, compelling, or just plain interesting to them. From the birth of the Internet to the proliferation of educational programming offered by IMAX, educational television, and museums, there are more opportunities for self-directed learning than ever before, much of this science-and health-related. In a typical day, a person might surf the Internet in a local library to track down information about arthritis, attend an amateur astronomy club meeting, watch a nature documentary on television, or interact with exhibitions on robotics at the local science center. All of these events are free-choice learning experiences, the most common type of learning in which we engage throughout our lives.

Where do knowledge-thirsty publics turn to learn about science and technology when not in school or at work? There are books. Despite the hype about declining literacy, the number of books sold per year in the United States is at an all time high; many are science- and/or technology-related (Achenbach, 1999; U.S. Bureau of the Census, 1996). There is television. Not only is television viewing up (Godbey, 2001; U.S. Bureau of the Census, 1996), but so too are the number and diversity of information-oriented programs, many of them science- and/or technology-related (Gross, 1997). There is the staggering growth of the Internet, and clearly science and technology topics are being communicated there also (Achenbach, 1999; Schwartz, 1998). And there are science-related museums and other free-choice science education settings such as zoos, national parks, aquariums, and science-technology centers. Not so long ago the vast majority of Americans would rather have been bound and gagged than visit a museum. Today museums, particularly science-technology-oriented ones, rank as one of the most popular out-of-home leisure experiences in the world, surpassing even sporting events in America (Association of Science-Technology Centers, 1999; Falk, 1998; Falk and Dierking, 2002).

There is no single right way to learn things, and no single place or even moment in which we learn. All of our learning happens continuously, from many different sources, and in many different ways. There are three main places in a society where we receive this guidance: schools and universities, the workplace, and the free-choice learning sector. All three are important; all three are essential for lifelong learning. There is clearly a need in our lives for formal education. Formal education is the place in which we are guided in the development of basic skills and introduced to new realms of knowledge. There is also a need in our lives for career-directed learning. The workplace is where we learn the skills and abilities necessary to do productive work, and in the process earn the income we need to sustain our lives. But there is also a need for free-choice learning. The free-choice learning sector is where we can tap into a vast array of resources, where we are provided an opportunity to explore the thousands of topics, whether shallowly or deeply, occasionally or frequently, that lead us to understand ourselves, our families, our society, and our world a little bit better. All of these educational sectors currently exist, all are large and vibrant, but one of these – the free-choice learning sector – has been largely ignored and underappreciated for the profound impact it has on learning in general, and science learning in particular. As a society, we have developed this bad habit of assuming that learning is only that thing we do in school. Now, as well as historically, most people acquire much of the knowledge, understanding, and information they require for their daily lives outside of school.

Some of you reading this paper may not believe this is true, but take a moment to do a thought experiment. Think of five topics that you know something about, any five topics. How did you come to know something about those topics? Where did you first begin to learn about them? Why did you learn about them? How do you stay current in that topic? If you are like most people, at least one of the topics you picked was related to your work. Hence, much of what you know about the topic you learned as part of on-the-job training. But what about the others? Institute research would suggest that the majority of the topics you listed represent a range of subjects relating to personal and avocation interests. Some of these may be topics traditionally taught in school, but many are not. Your interest in these various topics was likely developed early in life, maybe initially from friends or perhaps your family. Although you may have even gained some basic information about some of these topics in school, over time, because of your interest in the topics, you maintained and extended your knowledge by reading articles in magazines and newspapers. You also probably watched television shows on these topics, continued to talk to friends and family, perhaps even checked out a book or two on the topics from the library, or visited a museum somewhere along the way. Of course you may be saying that you learned about your hobbies such as cooking or vintage movies outside of school. But that the real substantive knowledge you possess – knowledge of history, literature, and science – you most certainly acquired in school. Perhaps.

Let's take science as an example. In the United States, ever since Sputnik, billions of dollars have been poured into schools to enhance the quantity and quality of science and technology education. These are subjects taught in every school in America, not once but repeatedly, from elementary through high school and college. However, on national tests of science and technology knowledge, most adult Americans fare poorly (Miller and Pifer, 1996). Only those with college-level courses in science do well on these tests. Of course what should we expect; the questions asked on these tests are typically college-level multiple-choice questions, many drawn straight from university textbooks. Does every American really need to know how a laser works or be able to define 'radiation' in order to be a productive, informed, and competent citizen? I do not think so. However, given the importance of science and technology in modern life, should every American know something about these topics? Of course, the answer is yes.

John Falk's suspicion was that Americans actually do know quite a bit about science and technology, but it is not a generalized 'textbook' type of knowledge. Rather, Americans' knowledge of science and technology is likely to vary widely and be very topic-specific. Depending upon need and interest, one person is likely to know a great deal about tropical fish biology and another about computers; few are likely to know a great deal about all areas of science and technology (most scientists do not know a great deal about other branches of science outside their specialization either).

Recently, John Falk and colleagues at the Institute launched an investigation to help determine how, when, where, and why people learn science (Falk and Coulson, 2000; Falk, 2001). To do this, they conducted two large-scale strategically sampled telephone surveys. In each study, they randomly called hundreds of Los Angeles residents (close to two thousand in all) in five representative communities in the Los Angeles area and asked them questions about their science and technology knowledge. These were average folks — some were poor, some were affluent, some had graduate degrees, some had not completed high school. Represented were young and old individuals of virtually every imaginable race, ethnicity, and background. They asked these people if they were interested in science and technology – overwhelmingly they said they were. Interest in science and technology seemed to be universal, true of virtually all individuals, regardless of education, race, ethnicity, or gender. They asked them if they felt they were knowledgeable in science and technology – by and large they thought they were "sort of knowledgeable." Then they asked each person to describe some area of science and/or technology in which they felt they knew more than the average person. They also asked people to tell them why they had that greater-than-average knowledge in this area of science and technology and from what source they acquired the knowledge.

Virtually everyone in the sample felt that there was at least one area of science and technology they had some reasonable knowledge of, a knowledge that exceeded the norm. The areas described ranged from astronomy to zoology. Some people described very specific areas of scientific knowledge such as the physics of the internal combustion engine or the physiological basis of depression; others gave more general categories of knowledge such as health or the environment. Most people claimed that the motivation behind their knowledge was simply interest and curiosity, although occasionally the motivation to learn about a topic was a personal crisis, such as the need to learn about the disease of an ill relative. Professional and work-related reasons were also commonly given. Across the board, though, at some point in each individual's life, something about the science and/or technology topic they claimed a special knowledge of had piqued their curiosity. And it was this curiosity for the subject which had primarily prompted them to continue pursuing greater knowledge and understanding of the subject.

Most fascinating of all were the sources of science and technology knowledge that the public identified. Roughly a third of the people surveyed claimed to have primarily learned their favored science topic in school. Just under a quarter of the sample said they learned their science on the job, as part of their work. However, the largest number of people, approximately half of all those surveyed, claimed to have learned about the science and/or technology topic during their leisure time, through some kind of free-choice learning experience. People described learning science and technology from the Internet, reading magazines and books, going to museums, zoos and aquariums, and participating in special-interest clubs and groups. Although schooling was an important source of scientific learning for some, it was not the primary source for most.

A recent study by the National Science Board supports these findings (Miller, 2001). Researchers found that 50% of American adults read a daily newspaper including articles on science and technology, 15% read one or more science magazines each month, and a majority of Americans watched one or more science television shows each month. Approximately two-thirds of adults visited a science center or natural history museum at least once a year and a third of Americans reported that they had purchased one or more books on science and/or technology topics during the preceding year. These studies lend tremendous support to the important role non-school sources play in sustaining lifelong learning in general and science and technology learning in particular. The data would suggest that even a traditional school subject such as science is not exclusively, or even primarily, learned in school. Similar investigations have been conducted to determine where the public learns history. And similar to these studies of science learning, it was found that the majority of Americans attributed their knowledge and understanding of history to free-choice learning sources such as family members and television, not to school or university.

The above is not intended as a condemnation of school-based learning. The point is merely to emphasize the fundamental role played by non-school-based learning. Each of America's three educational sectors significantly contribute to the science and technology learning of the public. However, of the three, the free-choice sector is far and away responsible for providing more people more educational opportunities more of the time than either of the others combined. Of the three, the free-choice sector is also the most diverse, fastest growing, and arguably the most innovative. Already, most of the learning in America occurs within the free-choice sector, and this reality will become even greater in the years to come.

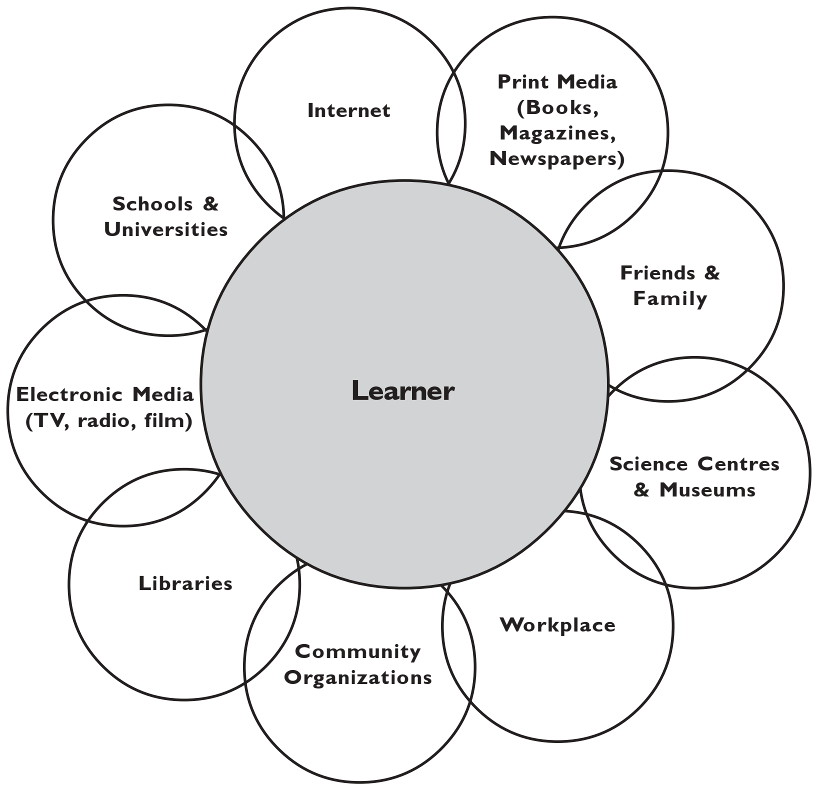
An infrastructure for free-choice science and technology education and research

The science and technology education infrastructure

Nearly a decade ago, educational evaluator Mark St. John proposed that we should rethink how we look at the entire learning enterprise, suggesting that the school and free-choice learning sectors (and I would add the workplace) be considered components of a single, larger educational infrastructure (St. John and Perry, 1994). He used the term 'infrastructure' to describe the system of supports, conditions, and capacities that permit the smooth functioning of daily life. Infrastructures represent essential undergirding for a variety of activities; for example, the highway infrastructure facilitates transportation, and an infrastructure of community services such as a fire and police department permits a community to function smoothly. The educational infrastructure in a community supports and facilitates the learning that takes place there. From this perspective, the learning infrastructure is vital to a nation's economic as well as intellectual and spiritual wellbeing. The educational entities that provide citizens with current and accurate knowledge and information, whether about health, politics, economics, the arts, or science, form the fundamental backbone of the knowledge economy. The explosion of the Internet and the World Wide Web provides significant testimony to the perceived value of having a readily accessible tool that can provide virtually anyone, anywhere, with any information, any time. The Web, though, is just one aspect of an ever expanding, and hopefully improving, network of learning resources available to the general public.

The science and technology learning journey of twenty-first-century citizens will require many way stations, each helping to fulfill part of the citizen's learning needs. What the world needs is a richly integrated, broadly supported educational infrastructure, a system of support that will enable millions of unique individuals to meet their widely varying science and technology learning needs any time of the day, at any point in their life. This basic educational infrastructure already exists, composed of schools and universities, the Internet, print and broadcast media, libraries, community-based organizations, the workplace, and friends and family (see Figure 1). Ideally, all of these educational entities work together to support and sustain science learning across the life span (Johnston, 1999).

Figure I
Science & Technology Learning Infrastructure



The science and technology educational infrastructure serves as a web of influence that shapes people's understanding, attitudes, aesthetic beliefs, etc., for although schools and universities are important, so are museums and science-technology centers, electronic media, increasingly the Internet, as well as community-based organizations, libraries, and a whole host of others. The entire science and technology educational infrastructure provides value and support to any nation, and the entire infrastructure needs to be valued and supported.

The implications of this infrastructure idea is that we look for science and technology teaching and learning in novel places. For example, we are currently working with the Astronomical Society of the Pacific, based in San Francisco, CA. With our assistance, over the last ten years they have been exploring and experimenting with ways to tap into the vast resource of amateur astronomers. With funding from the National Science Foundation, they have involved these astronomers in supporting elementary and middle school teaching in classrooms through "Project ASTRO" and are now involved in "Family ASTRO," an effort to provide fun and engaging astronomy experiences to families through the network of museums, science-technology organizations, and community-based organizations such as scouts. This effort represents a creative way of brokering connections within the science and technology education infrastructure.

Leadership in free-choice science and technology learning

However, it is not enough to recognize this infrastructure and to tinker around the edges; fundamental changes in how, when, and where we think about science and technology learning requires bold leadership to change the current status quo. Fortunately, two of the leading science and technology education organizations in the United States – one focused on practice and the other on research – are playing an important leadership role in this arena. In 1998, the National Science Teacher's Association (NSTA) published a policy statement on informal (free-choice) learning. In 2000, NSTA leadership established a Board seat representing this community of science educators, allowing them to play a more active role in the development of policy for this important national science and technology teaching organization.

And in the spring of 1999, an ad hoc committee focused on informal science education was created by the National Association for Research in Science Teaching (NARST) Board with the goal of exploring interest among NARST members for additional leadership by the organization in this arena; John Falk and I were appointed co-chairs for the Committee. A major task in 2000 was to survey NARST members about their perceptions of the NARST organization's positioning relative to out-of-school science and technology learning, including their interest in the organization increasing their profile in this research area. Findings suggested that members did support the idea, and a report detailing the findings of the survey and discussing its implications and recommendations for NARST was presented to the Board in September 2000. The Board and leadership of the NARST organization endorsed the findings and recommendations of the ad hoc committee, and directed us to develop a plan for a strategic initiative in this area. A major product of this endeavor is a policy statement in the area of out-of-school (free-choice) science education research that can be used by the NARST organization to promote and advocate the importance of out-of-school science learning and the need for scholarly research in the area (refer to Appendix A for a copy of the policy statement, and look for more information about it in a special issue of the *Journal for Research in Science Teaching*).

However, a policy statement is not enough; we need to act upon it to make the vision therein a reality. We need to create in some cases, and coalesce in others, an infrastructure for science and technology educators interested in facilitating and investigating this type of learning. There are a few existing efforts but they are diffuse, uncoordinated, under-funded, and lack the power and clout to be considered major players in the science and technology education arena. For example, the Search for Excellence in Science and Mathematics Education (SESAME) program at the University of California, Berkeley, has produced a number of leaders in the field over the years, including Dr. John H. Falk, Dr. Mark St. John, and Dr. Judy Diamond. For many years prior to his untimely death, Dr. John J. Koran, Jr., University of Florida, Gainesville, supported science education graduate students interested in research in this area (I was fortunate to have been one of those students), and Dr. Alan Friedman, Director of the New York Hall of Science, has also established such a program at New York University in collaboration with science education colleagues there. However, for the most part these programs have been small, informal, and awkward add-ons to the existing science education programs at those universities. What we have lacked as a developing field is an established program with a reputation to attract faculty and graduate students with a desire to focus their efforts on fundamental and applied research in this area.

Fortunately, there are a few initial efforts trying to change that reality. The University of California at Santa Cruz; The Exploratorium, an internationally recognized free-choice learning setting in San Francisco; and King's College, London, recently received a major CELS grant from the National Science Foundation to create a collaborative undergraduate and graduate program that will focus on this arena. They began developing the program this summer. In an independent but complementary effort, the Institute for Learning Innovation is in discussions with the Chair of the science education department and director of the Oregon Sea Grant Office at Oregon State University, Corvallis, Oregon, with the goal of developing a graduate program in free-choice science education there. Both of these efforts are young and deal with the myriad questions that plague any start-up programmatic effort at a university: 1) What should the curriculum for this program look like? 2) What relationship, if any, will it have with the traditional science education programs already existing at these universities? 3) How will students be recruited into the program? 4) What should the criteria for Master's and Ph.D.'s be? Despite these challenges, there is great excitement about the possibilities for innovation, both within the structure of these programs themselves, but also by the collaborative way these two programs are being conceived and conceptualized – the programs themselves represent innovative collaborations between entities within the science and technology education infrastructure. Unique times require unique solutions!

Advocating within the science and technology education community

So what can you do to participate in this exciting movement? First, I would encourage those of you involved in the international science and technology education community to play an advocacy role for this important type of science learning. If you are involved internationally, make sure that all parts of the science and technology education infrastructure are at the table as well. Invite fellow educators and researchers exploring this arena to participate in your international efforts. They have much to share and much to learn from you.

There is also much to do back in your own local communities. If you do not already know what is going on in the area of science and technology learning in other parts of the educational infrastructure, in your local community, find out. As you develop new efforts and sustain existing ones, ensure that *all* the science and technology education partners are involved.

Most importantly, we need to work together to educate administrators and politicians about this broader perspective of lifelong science learning. By more clearly identifying and describing the vast number of ways and places in which people of all ages learn science and technology, we stand a much greater chance of transforming education and subsequent learning to meet the demands of a changing world.

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Appendix A

National Association for Research in Science Teaching "Informal (Free-Choice) Science Education"

Policy Statement

Defining the Domain

'Informal learning' is the most commonly applied term for the science learning that occurs outside of the traditional, formal schooling realm (pre-college, university, and advanced degrees). It has significant limitations because it artificially delimits efforts to describe the type of real world learning that humans engage in daily; learning that occurs across a broad spatial and temporal context, both inside and outside of schooling. As a growing number of researchers choose to try and understand how people come to learn about science, it has become increasingly apparent that such understanding must include more than just the experiences of schooling.

At the core of this effort to understand real world science learning is a firm belief that learning rarely, if ever, occurs and develops from a single experience. Rather, learning in general, and science learning in particular, is cumulative, emerging over time through myriad human experiences, including but not limited to experiences in museums, schools, while watching television, reading newspapers and books, conversing with friends and family, and, increasingly frequently, through interactions with the Internet. The experiences children and adults have in these various situations dynamically interact to influence the ways individuals construct scientific knowledge, attitudes, behaviors, and understanding. In this view, learning is an organic, dynamic, never-ending, and quite holistic phenomenon of constructing personal meaning. This broad view of learning recognizes that much of what people come to know about the world, including the world of science content and process, derives from real world experiences within a diversity of appropriate physical and social contexts, motivated by an intrinsic desire to learn.

Historically, much of the research on science learning outside of school has occurred within museum-like settings. Learning from museums, or other comparable educational institutions (zoos, aquariums, nature centers, etc.), actually represents a very nominal number of the situations in which this type of learning occurs. However, the growing body of research on learning in and from museum-like settings provides an important baseline of understanding about learning in such free-choice situations. Clearly lacking, though, are comparable studies of learning from film, radio, community-based organizations like scouts and summer camps, home and friends, the workplace, the Internet, and a whole range of other real-world situations.

As the desire to investigate learning in these settings increases, the need for an enhanced theory of real-world, lifelong learning becomes critical. The conceptual and methodological challenges engendered by this type of research have only begun to be understood. The National Association for Research in Science Teaching has an opportunity to play a significant role in fostering and advancing research into the long-term, cumulative nature of science learning – learning that is strongly socioculturally mediated and occurs across a wide range of physical contexts beyond schooling. The result will be a more holistic, large-scale understanding of the entire learning process, both inside and outside of schooling environments.

Implicit in this thinking is a discussion of an appropriate moniker for this area of research.

There are many possibilities, (e.g., out-of-school, free-choice, lifelong, public understanding of science, etc.) but there was unanimous agreement among members of the ad hoc committee that it should not be the current term: 'informal science education.' The ad hoc committee is still considering the appropriate one; however, they do know that it needs to reflect the following: learning that is self-motivated, voluntary, and guided by the learner's needs and interests – learning that is engaged in throughout his or her life (*Informal Learning Environments Newsletter*, May/June, 1998; *Daedalus*, 1999; Teachers College Press, 2001; Falk and Dierking, [2002]).

Clearly there is a trend toward this type of research in the field, which NARST has participated in by establishing Strand 9, supporting the joint AERA/NARST session at the Year 2000 annual meeting and by publishing a paper set devoted to the topic in the *Journal for Research in Science Teaching*. However, it is the ad hoc committee's feeling that the NARST organization could be doing more to support scholarship in this arena. In the past 5 to 10 years, interest in this area of research has grown tremendously. The American Educational Research Association now has an Informal Learning Environments Special Interest Group with a bi-yearly newsletter. In 1998, the journal *Science Education* initiated a permanent special section on Informal Science Education, due in great part to the success of a special issue devoted to that topic in 1997, Volume 81(6), and in 1998, the National Science Teachers Association published a policy statement on this type of learning, created a board position, and recently published a two-volume series on the topic. These are all important efforts, but the ad hoc committee still feels there is a leadership role that could be played by the NARST organization.

NARST has a potential opportunity to take a leadership role by supporting research in this area of out-of-school learning. By raising the profile of such research, the committee feels that NARST would demonstrate its understanding of the fundamental role that such learning plays in the lives of children and adults across the life span. By promoting a broader definition and framework for this type of learning and efforts to investigate its relationship to learning from schooling and workplace environments, NARST has an opportunity to shape a larger vision for the twenty-first-century learner that includes out-of-school (free-choice) learning.

Issues related to conducting research in this domain

In the past decade, research in neuroscience has demonstrated that learning is strongly influenced by prior knowledge and experience, interest and motivations, all shaping the expectations that people have for a learning experience. Learning is also a cumulative process – it can take days, weeks, or even months for new experiences to be sufficiently integrated with prior knowledge before learning is measurable, let alone noticeable, even to the learner. New data also suggests that most learning has more to do with consolidation and reinforcement of previously understood ideas than with the creation of totally new knowledge structures. And neuroscience research also demonstrates the importance of motivation, interest, and emotion in the learning process itself, suggesting that when people are interested and curious about something, there is a high possibility that they will follow up on that feeling with action, resulting in meaningful learning.

To frame research to investigate such meaningful learning, these aspects need to be considered:

1) Such learning is self-motivated, voluntary, and guided by learners' needs and interests, so certain aspects of learning are critical to investigate, e.g., the role of motivation, choice and control, interest and expectations in the learning process.
2) The physical setting in which such learning takes place is extremely important, so this learning needs to be investigated in authentic contexts.
3) Such learning is strongly socioculturally mediated, so designs need to offer opportunities to explore social and cultural mediating factors, including the role of conversations, social learning networks,

cultural dimensions, and the use of groups, rather than individuals, as the unit of analysis.

4) Learning is a cumulative process, involving connections and reinforcement between the variety of learning experiences a person encounters in their life: at home, during schooling and out in the community and workplace. Designs need to offer opportunities to investigate all dimensions of learning and their connections in a variety of settings across a span of time which will allow us to understand how these experiences are used and connected to subsequent experiences longitudinally.
5) Learning is both a process and a product so we need to investigate the processes of learning as well as the products of learning.
6) The very nature of such learning requires multiple, creative methodologies for assessing it in a variety of ways under a variety of circumstances. Thus, innovative research designs, methodologies, and analyses are critical (e.g. conversation analysis, constructivist tools such as concept mapping and Personal Meaning Mapping, social learning network analysis, and hierarchical linear modeling).

Recommendations

The committee recommends several ways that the NARST organization could provide leadership in this area including:

1) Promote an awareness of the vast number of ways, ages, and places in which a person learns science and the importance of conducting scholarly research in this arena;
2) Play an advocacy role by bringing to the educational community's (science educators in a variety of settings, administrators, politicians, and researchers) attention the place and value of these settings;
3) Encourage the search for methodologies that are appropriate to this area of research and support their refinement and validation;
4) Continue to support collaborative sessions such as the successful jointly sponsored AERA/NARST pre-conference workshop at the 2000 meeting;
5) Support and encourage collaborative research, with out-of-school (free-choice learning) science education researchers being natural research partners with others in NARST doing more formal research, for example, encouraging research that explores intersections between technology and out-of-school science learning might be beneficial; and,
6) Initiate ideas for continued dialogue such as the creation of a web-based discussion group or special area of the web site to include information regarding cutting edge research on learning in out-of-school (free-choice) learning settings.

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